

Protein Nutrition in Red Deer (*Cervus elaphus*)

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Abstract Red deer can adjust to seasonal change of forage quality to maintain a relatively constant crude protein level (21.1 ± 4.0 , 14.7 ± 1.0 , 11.1 ± 1.1 and 6.5 ± 0.8 in spring, summer, fall and winter, respectively). Apparent protein digestibility is variable from 99.9% to 97.5%, depending upon season and forage type. True protein digestibility is 99%. Digestion of protein is significantly influenced by phenolics in diets. Minimum digestible energy intake of $153.5 \text{ kcal/kg}^{0.75}/\text{day}$ is necessary to maintain a positive nitrogen balance. Red deer recycles 18-85% of the urea produced and urea kinetic parameters (urea pool size, urea entry rate and urea excretion rate) are correlated to plasma urea concentration. Rumen $\text{NH}_3\text{-N}$ production changes with season, but seasonal changes in other $\text{NH}_3\text{-N}$ kinetic parameters ($\text{NH}_3\text{-N}$ concentration, $\text{NH}_3\text{-N}$ pool size and $\text{NH}_3\text{-N}$ outflow rate) are in dispute. Protein metabolism may be promoted in response to cold stress. Endogenous urinary nitrogen is 0.09 (red deer) and 0.16 $\text{g N/kg}^{0.75}/\text{day}$ (elk), and metabolic fecal nitrogen is 5.58 g N/kg dry-matter intake. Protein requirements ranges from 100 g/kg DM to 170 g/kg DM for red deer of various ages and physiological stages. In conclusion, the knowledge of protein nutrition of red deer is limited. Much work is urgently needed in metabolism and requirements of protein before the appropriate feeding standard of red deer is coming.

Key words: red deer, *cervus elaphus*, protein, nutrition

Introduction

Red deer are important big game animals, distributed widely in Asia, Europe and North America. In recent years, the farming of red deer is becoming an important form of livestock diversification which taps new markets and pasture resources. Throughout the world, more than 1,186,900 red deer are reared on farms (Haigh and Hudson 1993). Thus, understanding the nutritional requirements of red deer is fundamental to the management of wild populations and the development of feeding standards for farmed deer. Protein is the most important component of animal tissues and a continuous supply of it is needed throughout life. For red deer, the knowledge of protein nutrition is generally limited. The present review attempts to compile and summarize the recent studies and developments in this field.

Dietary Protein Content

Wild red deer

Crude protein (CP) content is commonly used as an index of dietary quality in wild ungulates. Although the

digestible crude protein (DCP) system does not completely account for the dynamics of ruminal fermentation and the potential loss of nitrogen as ammonia (Orskov 1982, Sniffen et al. 1992; Webster 1992), at present, NRC system and some new protein evaluation systems (PDI system, Verite and Peyraud 1989, the Cornell Net Carbohydrate and Protein System, Sniffen et al. 1992) seem to be very difficult to apply to wild ruminants due to lack of basic research on protein nutrition.

Although wild red deer inhabit various habitats and eat numerous forage species which vary considerably in quality, they can adjust to maintain a relatively constant level in dietary CP, compared with the variable CP content in forages (Fig. 1, 2). Dietary CP varies seasonally, declining from spring to winter (Fig. 1, average dietary CP content are 21.1 ± 4.0 , 14.7 ± 1.0 , 11.1 ± 1.1 and 6.5 ± 0.8 in spring, summer, fall and winter, respectively).

Farmed red deer

In the farming of red deer, supplemental feeding is necessary in some critical periods (Kozak et al 1994). CP contents of concentrates, forages and typical com-

pounded diets used in supplemental feeding of red deer are summarized in Table 1.

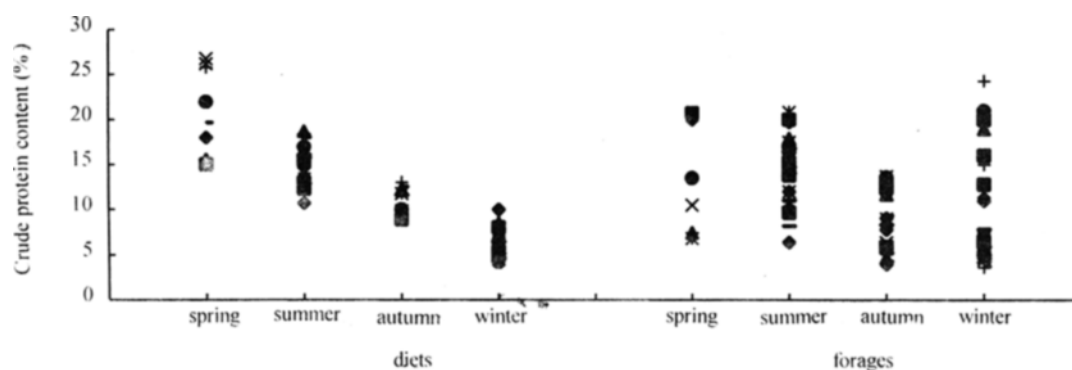


Fig. 1. Crude protein content in diets and forages of red deer

(Data from Baker and Hobbs 1982, Collins and Urness 1983, Hobbs et al. 1983, Rowland et al. 1983, Morgantini and Hudson 1985, 1989, Canon et al 1987, Happe et al. 1990, Jenkins and Starkey 1993, McCorquodale 1993, Merrill et al. 1995; own unpublished data). Forages are classified into graminoids (grasses and sedges), forbs and browses.

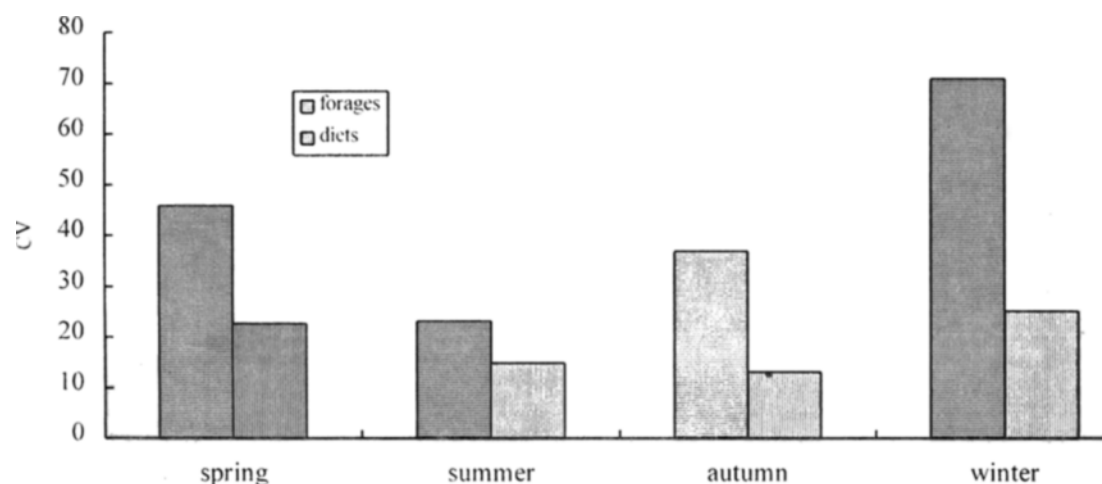


Fig. 2. Coefficients of variation of crude protein content in forages and diets of red deer

(Data source is the same as Fig. 1)

Table 1. Crude protein content (%DM) of concentrates, forages and typical compounded diets used in supplemental feeding of red deer (From Haigh and Hudson, 1993)

Concentrates				Forages				Compounded diets*	
Barley	11.1	Beet molasses (dry)	4.4	Alfalfa (mature pasture)	20.0	Brome hay	9.7	Ministik	16.6
Wheat	12.0	Peas	30.0	Alfalfa (1st cut hay)	18.0	Crested wheatgrass pasture	14.0	Michigan State University	17.0
Oats	13.3	Canola meal	40.6	Bluegrass pasture	18.7	Crested wheatgrass hay	14.0		
Corn	10.1	Soybean meal	49.9	Bluegrass (hay)	10.3	Timothy pasture	18.0		
Beet pulp (dehydrated)	9.7	Alfalfa/barley pellets	16.0	Brome pasture	18.0	Timothy hay	9.1		

* Dehydrated alfalfa, Barley, Wheat shorts, Corn, Soybean meal, Soybean oil, Beet pulp, Molasses, Monocalcium/dicalcium phosphate, Salt, Trace mineralized salt, Vitamins A, D, E mix, Binder/anti-mould

Protein Digestion

Variable apparent digestibility coefficients for dietary protein were reported (Table 2) and seasonal change in apparent digestibility is expected and observed (Westra

and Hudson 1981, Nelson and Lege 1982, Domingue et al., 1991, Freudenberger et al. 1994a). In the study by Robbins et al. (1981), elk calves consuming milk showed the highest apparent digestibility coefficient (Table 2). This results seems to support the conclusion that apparent protein digestibilities (APD) are highest

in neonates (Robbins 1983). Negative apparent digestibility coefficients were reported by Mould and Robbins

(1981) and a curvilinear relationship often exists between APD and dietary protein content (Fig.3)

Table 2. Apparent protein digestibility (APD) (%DM)

Animal	Sex	Age	Body weight	diets	CP	APD	References
red deer	F	3 yr.	53 and 55 kg	high-N diet	16.6	73	Maloiy et al. (1970)
				low-N diet	5.3	26	
red deer	M	Calf	40 kg	mixed concentrates and dried grass	16.0	74.6±9.6 (low intake)	Simpson et al. (1978)
						71.8±0.7 (high intake)	
elk	-	>1 yr.	-	Alfalfa	3.8-29.3	34.0±26.1	Mould and Robbins (1981)
wapiti	M	Calf	-	Pellet ration (barley, wheat, bran, beet pulp beet, molasses)	17.2	72.5 (indoor)	Westra and Hudson (1981)
						70.5 (outdoor)	
elk	M	Calf	-	Alfalfa hay	17.6	70.6	Robbins et al. (1981)
				Formulated milk	5.7	97.5	
red deer	F	-	94.8±5.5kg	Chaffed lucerne hay	17.8	67.9 (summer), 63.0 (winter)	Domingue et al. (1991)
red deer	M	3-5 yr.	-	Chopped lucerne hay	20.3	74.9 (winter)	Freudenberger et al. (1994a)
					20.5	71.4 (summer)	
					22.3	70.8 (summer restricted)	
red deer	M	3-5 yr.	117.7±3.2kg	Red clover Ryegrass/white clover	27.4	83.1	Freudenberger al (1994b)
					18.4	76.5	

Note: CP - Crude protein content in diets

If the excretion of metabolic fecal nitrogen remains constant and other dietary components have either no effect or a constant effect, the true protein digestibility can be estimated as the regression slope between protein intake and apparent digestible amount (Robbins 1983). According to this approach, red deer has a higher true protein digestibility (99%) (Fig.4) than the average of wild mammals (88.7±7.1%) (Robbins 1983) and those of other wild ruminants (Table 3).

Table 3. True digestibilities of dietary protein by wild ruminants (From Robbins, 1983)

Species	Diet	Digestibility coefficient
Bush duiker	Pelleted diet	83.5
Caribou and reindeer	Pellet and lichen diets	78.8
Eland	Pelleted diet	83.2
Hartebeest	Pelleted diet	87.4
Red deer	Pelleted diet	96.0
Thomson's gazelle	Pelleted diet	84.7
White-tailed deer	Pelleted diet	84.4
White-tailed deer	Hay	89.4
Bison	Hay	96.8
Elk	Hay and browse	98.0
White-tailed deer and mule deer		95.7

Digestion of protein can be influenced by soluble phenolics in red deer (Mould and Robbins 1981). Mould and Robbins (1981) indicated that the APD of those forages and mixed ration which contains high levels of phenolics were from 11 to 20% of predicted values at the same protein content as the phenolic-free

rations. The role of soluble phenolics in reduction of protein availability was further confirmed in other wild ruminants (Robbins et al. 1987). The equation predicting digestible protein of forages ($Z = -3.87 + 0.9283X - 11.82Y$, Z- digestible protein, g/100g feed; X- crude protein content, %; Y- BSA precipitation, mg per dry matter forage), was also thought to be applicable for other large-sized cervids including red deer (Hanley et al. 1992), although it was developed in mule deer and white-tailed deer (Robbins et al. 1987).

Protein Metabolism

Protein metabolism is affected by both biological and environmental factors. The biological value and urea recycling are two main factors affecting protein metabolism. Biological values are not constant, but vary with many other factors (protein source, amino acid composition, mode of protein digestion etc.) (Robbins 1983). Biological values of absorbed dietary nitrogen for red deer decreased from 100 to 42% as dietary CP increased from 5.6 to 29.3% (Mould and Robbins 1981). The same trends were also observed in other ruminants and mammals (Robbins 1983). The decrease in biological value may result from less efficient use of dietary protein with increasing urea production, reduced urea recycling and increased urea excretion (Mould and Robbins 1981).

Absorbed nitrogen that is not used in protein synthesis can be converted to urea in the liver which serves both as a source of protein and as a buffer to the rumen

microbial environment against dietary nitrogen deficiency (Waldo, 1968). Thus, urea recycling represents a means of conserving nitrogen when ruminants are consuming poor quality forage (Robbins et al. 1974). Knowledge of urea kinetics may be important in understanding the total efficiency of nitrogen utilization. Some parameters of urea kinetics were measured in red deer (Westra, 1978; Mould and Robbins, 1981). Urea degradation ranged from 0.66 to 1.98 g N/kg^{0.75}/day in the study by Mould and Robbins (1981), which were higher than the values (0.47-1.18) obtained by Westra (1978). The percentage of urea recycled by red deer was highly variable, ranging from 17.6% for fresh wheat herbage to 85.3% for timothy (Mould and Robbins, 1981), but amounts of urea recycled in red deer are comparable to those determined for other ruminants: 0.34-0.66 g N/kg^{0.75}/day for caribou (Wales et al., 1972), 0.45-1.38 g N/kg^{0.75}/day for white-tailed deer (Robbins et al., 1974), 1.17-1.99 g N/kg^{0.75}/day for cattle (Mugerwa and Conrad, 1971), and 0.05-0.59 g

N/kg^{0.75}/day for sheep (Nolan et al., 1976). Close correlation of urea kinetic parameters (urea-nitrogen excretion rate, urea pool size and urea entry rate) to plasma urea concentration were observed in red deer (Mould and Robbins, 1981) because a main approach for urea entering the rumen is through the blood. Urea pool size and urea entry rate were positively linearly correlated to plasma urea concentration and a curvilinear relationship was observed between urea-nitrogen excretion rate and plasma. Percentage of urea recycled increased with decrease of plasma urea (Mould and Robbins, 1981). However, high levels of urea recycling may not imply greater efficiency of nitrogen utilization because of availability of carbon substrates for net protein synthesis and endogenous protein catabolism (Norton et al., 1978). Another important consideration to improve the efficiency of nitrogen utilization is energy intake. Mould and Robbins (1981) estimated that minimum digestible energy intake of 153.3 kcal/kg^{0.75}/day was necessary to maintain a positive nitrogen balance.

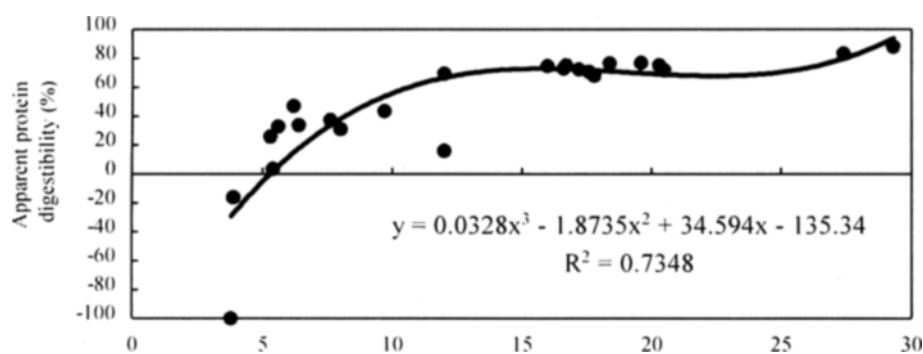


Fig. 3 Apparent protein digestibility of red deer as a function of dietary crude protein content

Data from Maloix et al. 1970; Simpson et al. 1978; Mould and Robbins 1981; Westra and Hudson 1981; Robbins et al. 1981; Domingue et al. 1991; Freudenberger et al. 1994a,b)

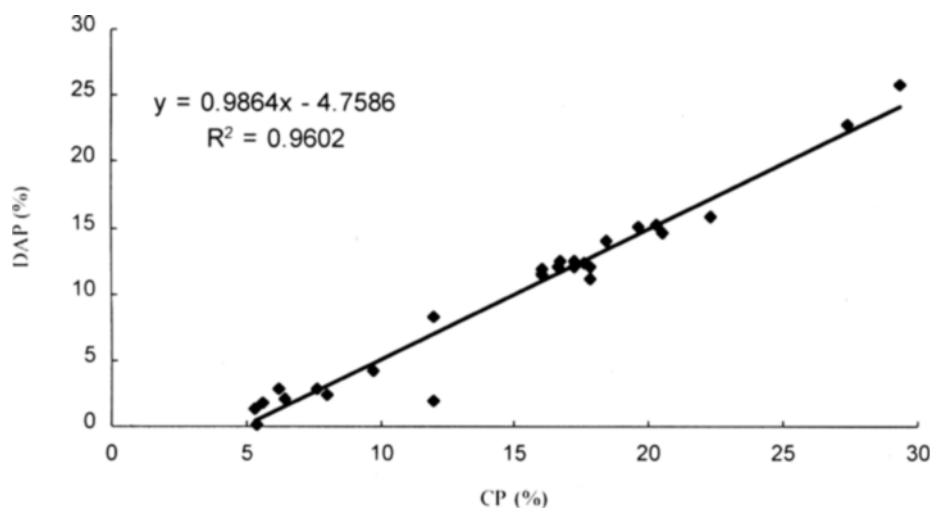


Fig. 4. Relationship between digestible amount (DAP, %, apparent protein digestibility × dietary crude protein) and dietary crude protein (CP, %)

(Data source is the same as Fig. 3)

Environmental constraints on protein metabolism receive little attention. When red deer calves were exposed to cold stress, nitrogen excretion was elevated and nitrogen balance reduced, which suggests that protein oxidation contributes to cold thermogenesis, nearly 30% (Simpson et al. 1978). This was further confirmed by the observation that red deer showed a seasonal change in nitrogen balance, with an increase in summer compared with winter (0.278 vs. 0.107 g N/kg^{0.75}/day, Domingue et al. 1991; 0.63 vs. 0.30 g N/kg^{0.75}/day, Freudenberger et al. 1994a).

Most ruminal bacteria can use NH₃-N as a source of nitrogen. Rumen NH₃-N concentration can affect not only microbial protein synthesis (Bondi 1987), but also the transfer of urea across the rumen wall, thereby urea recycling (Orskov 1982). Although rumen NH₃-N concentrations of red deer were reported in some studies (Hobson et al., 1976, Waghorn and Stafford, 1993), NH₃-N kinetics in rumen was recently studied in red deer (Domingue et al., 1991, Freudenberger et al. 1994a,b). In comparative study of red deer, goats and sheep, red deer showed an increase from winter to summer in rumen NH₃-N concentration, rumen NH₃-N pool size and NH₃-N outflow from rumen, whereas both sheep and goats showed no seasonal changes (Domingue et al. 1991). However, Freudenberger et al. (1994a) observed that rumen NH₃-N concentration and rumen NH₃ outflow were not affected by season of feeding, but they noticed a seasonal increase in the rate of rumen NH₃ production which was demonstrated to be independent of changes in voluntary feed intake (VFI). Increased rumen NH₃-N production may be important for maintaining fiber digestion as VFI increases during summer, especially when the diet is high in lignin and low in nitrogen (Freudenberger et al. 1994a). Compared with sheep, red deer had lower value in NH₃-N kinetic parameters in winter, but there were no differences between deer and sheep in these measurements in summer (Domingue et al. 1991). In contrast, Waghorn and Stafford (1993) observed higher rumen NH₃-N concentrations in red deer than that of sheep in vitro digestion. Compared with sheep and goats, the lowest rumen ammonia production rate (IRL) and the difference value between IRL and rumen NH₃-N outflow rate which represents the combined values for NH₃-N incorporated into microbial N and total NH₃-N absorbed through the rumen epithelium may imply that the proportion of bacteria nitrogen derived from rumen NH₃-N tends to be lowest in red deer.

Protein Requirements

The maintenance requirement of red deer for protein is

a dynamic function involving digestibility and biological value of dietary nitrogen, metabolic weight of the animal (endogenous urinary nitrogen, EUN), and dry-matter intake (metabolic fecal nitrogen, MFN) (Mould and Robbins, 1981). EUN determined in red deer were 0.09 g N/kg^{0.75}/day by Maloiy (1968) and 0.16 g N/kg^{0.75}/day by Mould and Robbins (1981), which are comparable to the 0.13-0.19 g N/kg^{0.75}/day for cattle of similar weight and maturity (ARC, 1965), 0.08 g N/kg^{0.75}/day for roe deer (Eisfeld, 1974) and 0.11 g N/kg^{0.75}/day for white-tailed deer (Robbins et al., 1975). MFN depends upon both food intake and quality of the ingested food. MFN of 5.58 g N/Kg dry matter intake determined for red deer (Mould and Robbins, 1981) was higher than the average of wild ruminants (4.97 (1.34) (Robbins, 1983). Fecal nitrogen content has commonly been used as an index of dietary quality of wild ungulates, including red deer (Gates and Hudson, 1979; Leslie and Starkey, 1985; Morgantini and Hudson, 1989; Gogan and Barrett, 1995). However, relationship between fecal nitrogen content and dietary nitrogen content may be variable due to many other factors involved in this relationship. In calves of red deer, fecal nitrogen content does not closely reflect dietary nitrogen content (Cook et al. 1994). More important, recent observation that the soluble phenolics, or tannin result in the elevation in fecal nitrogen excretion, severely questions the usefulness of the fecal nitrogen index (Robbins et al. 1987).

The maintenance requirement for protein can be estimated by combining above EUN and MFN. Mould and Robbins (1981) developed a computer program to predict minimum dry-matter intakes and nitrogen intakes required by red deer to meet their maintenance nitrogen requirements at various dietary protein concentrations. However, until recently, protein requirements for production and growth processes of red deer have to be extrapolated from domestic ruminants using the factorial approach, due to the limited information on the protein nutrition at various physiological stages (Table 4, Fig. 5, 6).

Table 4. Protein requirements for red deer (Data from Adam, 1991)

Animals	Age/status	Season	CP (g/kg DM)
Calves	3 - 5	autumn	170
	6 - 8	winter	100
	9 - 15	spring/summer	120 - 170
Hinds	dry	autumn/winter	100
	pregnant	spring	140
	lactating	summer	170
Stags	weight loss	autumn/winter	100
	weight gain	spring/summer	120

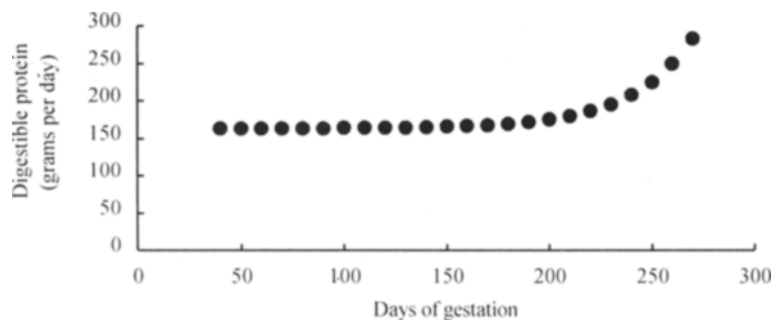


Fig. 5 Digestible protein required by a 260-kilogram elk during gestation (Data from Nelson and Legee, 1982)

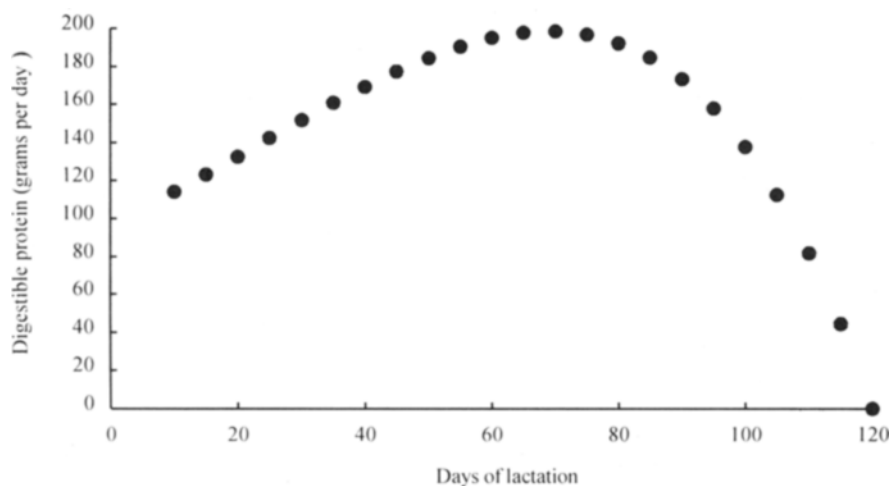


Fig. 6 Digestible protein required by a 260-kilogram elk during lactation (Data from Nelson and Legee, 1982)

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- I red deer was used as a general term in this paper, including wapiti and elk. No distinction was made about use of red deer and wapiti or elk, unless necessary.*